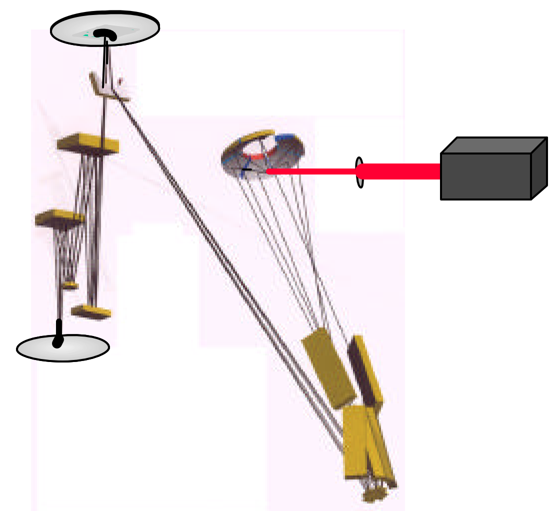
Extreme Ultraviolet Lithography for Next Generation IC's

Outline:
- Lithography challenges
- Technology description
- Key developments
  - Alpha tool
  - Source
  - Masks
  - Imaging results
- Cost of Ownership
- Advantages



Charles (Chuck) W. Gwyn, Program Director
Intel Corporation & EUV LLC

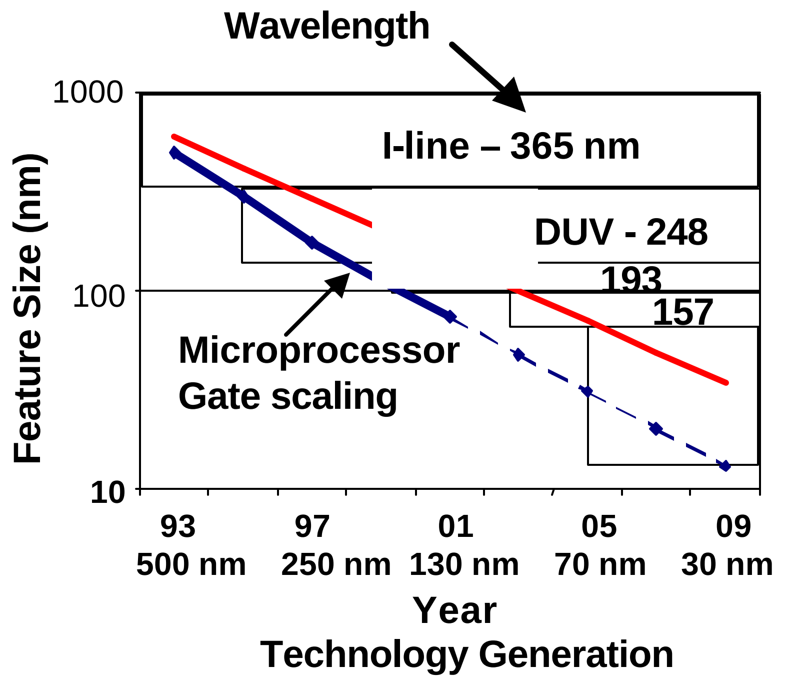
Cahners MDR Microprocessor Forum 2000
October 11, 2000
Xtreme Semiconductor Process Technology

Lithography Importance - *Need for Xtreme Processing*

- **Microprocessors and memory circuits follow Moore's Law**
  - ***Complexity doubles – 18 months***
  - ***Cost remains constant***

- **Lithography provides the enabling manufacturing technology**
  - ***Optical lithography scales with exposure wavelength***
  - ***Feature size =*** $k_1 \frac{\lambda}{NA}$

- **Traditional optical lithography nearing end of economical manufacturing**
  - ***New solution required !***



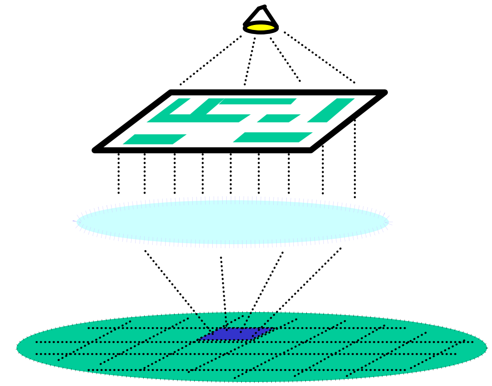
Extreme Ultraviolet Lithography
- ***13.4 nm wavelength***
- ***Use for 70 nm ~ 2005 timeframe***

EUV LLC

Extreme Ultraviolet and Optical Lithography

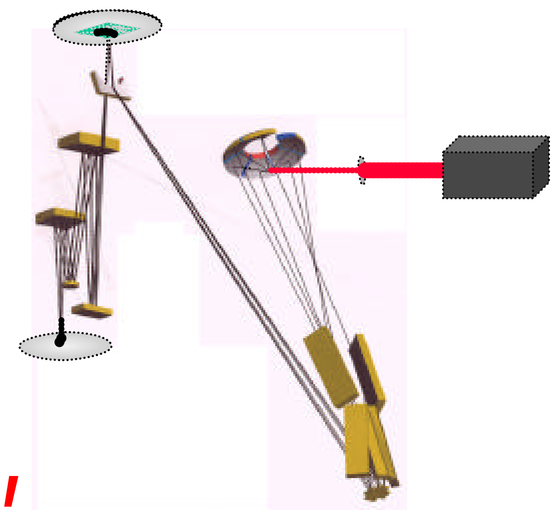
Similarities

- Resolution and Depth of focus scale with NA and wavelength
- Uses reduction optics (4x)
- Builds on optical lithography experience base
- Supports optical extension tricks – off axis illumination, phase shift masks, OPC
- Employs step and scan printing



Differences – Disruptive Technologies

- Uses very short 13.4 nm light
- 13.4 nm radiation absorbed by all materials
- Requires reflective optics coated with quarter-wave Bragg reflectors
- Uses reflective reticles with patterned absorbers
- Vacuum operation
- Unique source for EUV light



Requires New Development Approach !

New approach required for tool development

Business Constraints

- Revolutionary new technology expensive
- Requires diverse expertise - unavailable at tool makers
- Uses special facilities and metrology
- Aggressive development schedule
- Demands non-evolutionary development approach

Solution

- Establish a virtual company
- Objectives
  1. Develop basic technology
  2. Demonstrate technology with “Proof of Concept” Alpha Tool
  3. Reduce implementation risks and transfer the technology to Stepper Companies for production tools

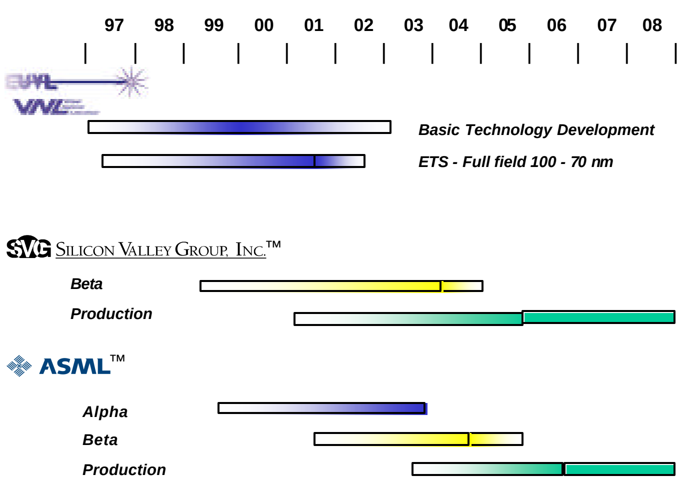
Implementation Approach

- **Intel formed the EUV LLC consortium with AMD, Infineon, Micron, and Motorola**
  - *Funding*
  - *Management*
  - *Mask development*

- **LLC contracted with Virtual National Laboratory - Lawrence Berkeley, Lawrence Livermore, and Sandia National Laboratories**
  - *Technology expertise and facilities*
  - *Basic R & D*
  - *Design/fabrication of alpha tool*

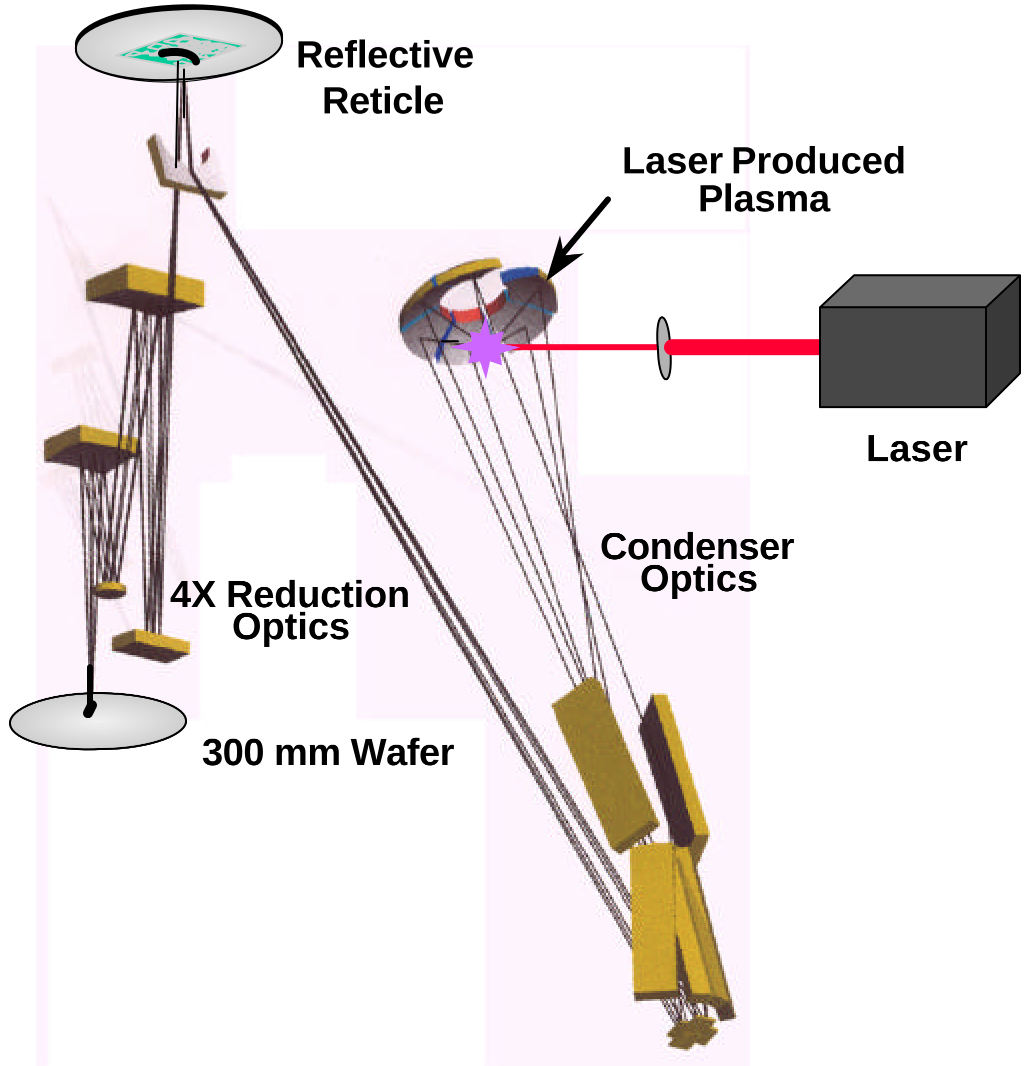
- **LLC partnered with ASML and SVGL**
  - *Beta tools*
  - *Production tools*

Development Schedule



Exposure Tool Schematic

Ring Field Illumination
Scanning reticle and wafer stages



Aspherical, multilayer coated, reflective optics (Finish < 3 Å, l/4 coatings - Control ~0.1A)

EUV imaging using UTR

Alpha Tool Optical System - Challenges

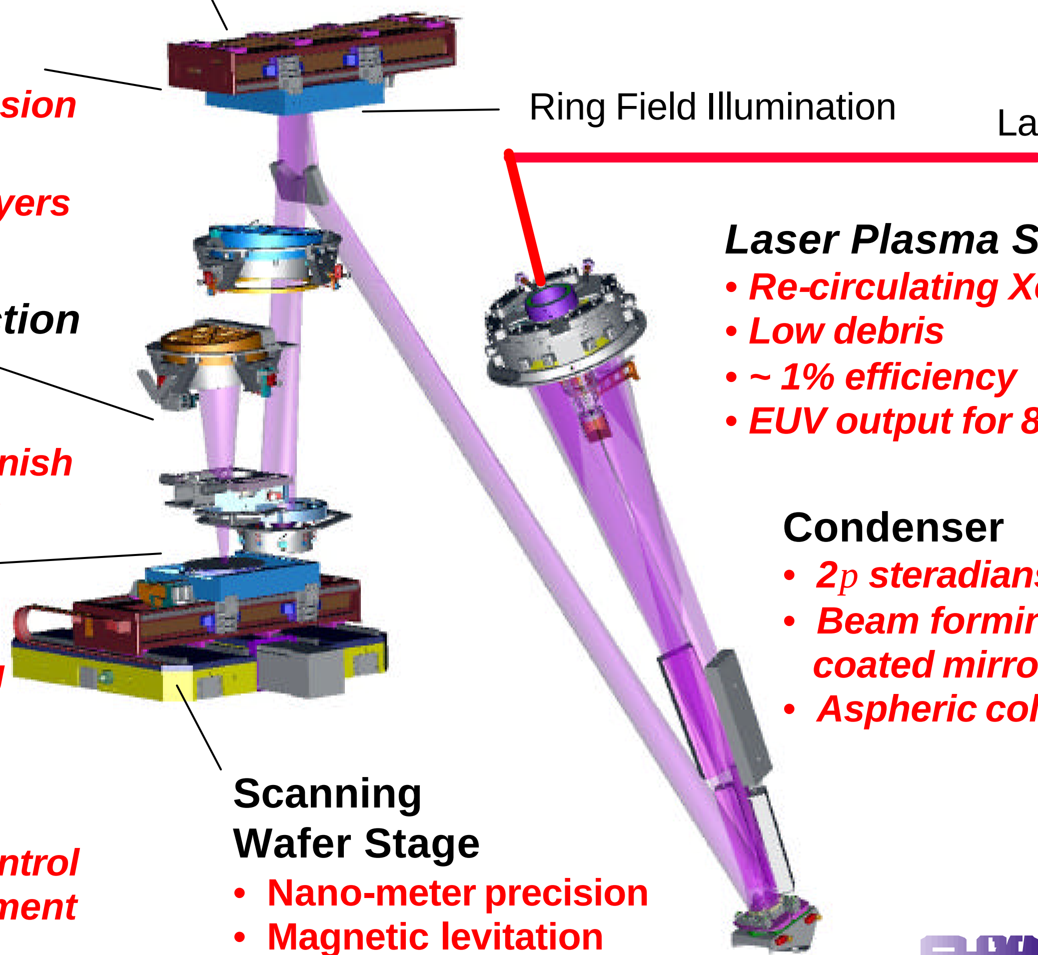
Scanning Reticle Stage
- *Electrostatic clamping*

Reflective Reticle
- *Low thermal expansion substrates*
- *Low defect multilayers*
- *Particle protection*

Reflective Projection Optics (4x)
- *Aspheric optics*
- *Precision figure/finish*
- *Tuned multilayers*

Wafer
- *Thin resist*
- *Low outgassing*

Vacuum System Operation
- *Environmental control*
- *Thermal management*

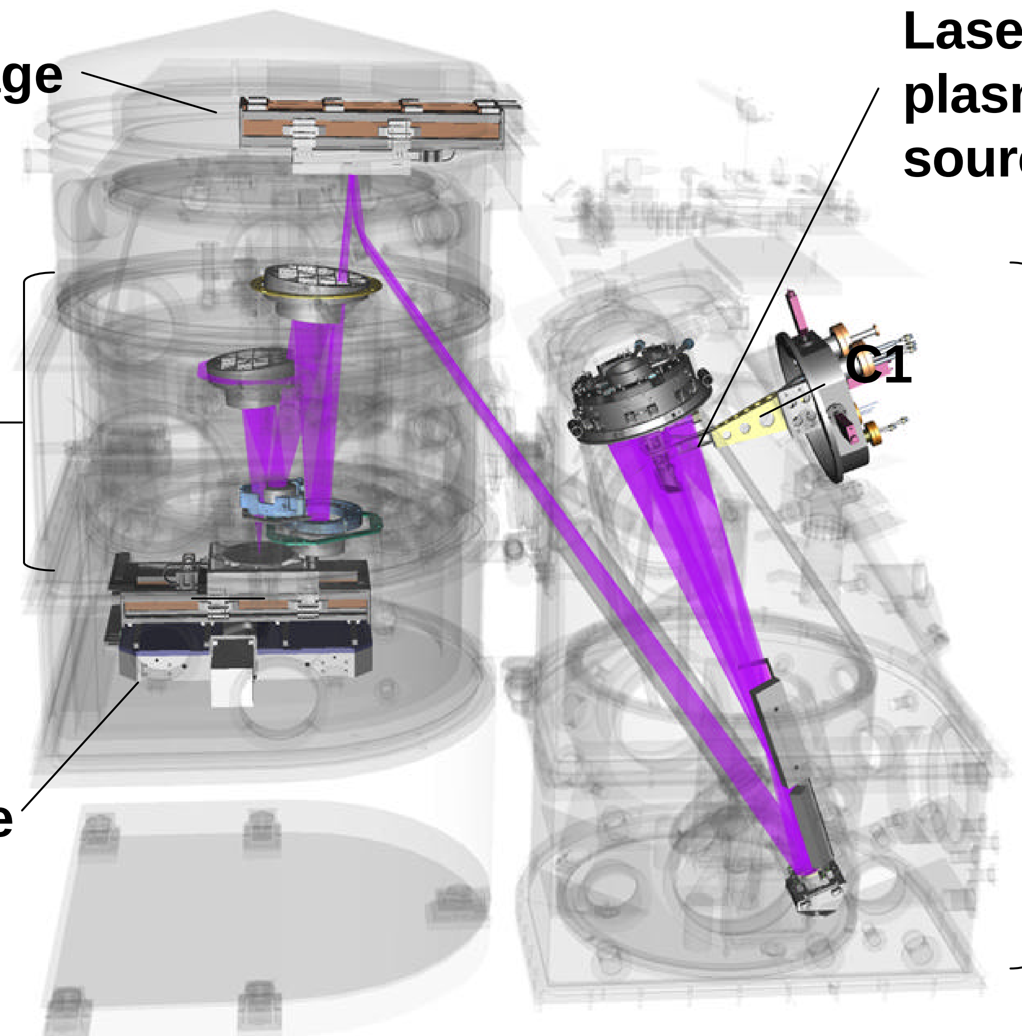


Scanning Wafer Stage
- **Nano-meter precision**
- **Magnetic levitation**

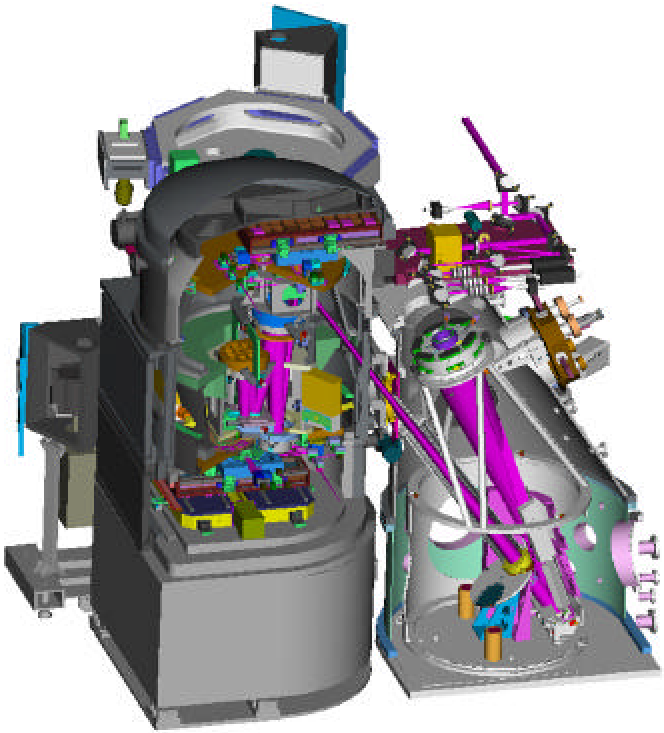
Laser Plasma Source
- *Re-circulating Xe gas target*
- *Low debris*
- *~ 1% efficiency*
- *EUV output for 80 wafers/hour*

Condenser
- *2p steradians collection*
- *Beam forming multilayer coated mirrors*
- *Aspheric collection optics*

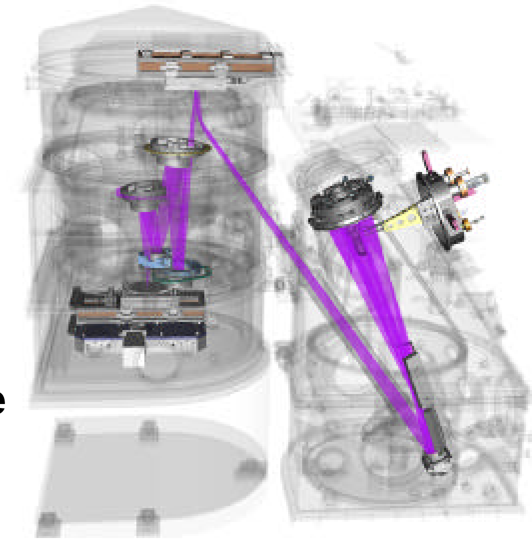
Challenges met with alpha tool demonstration

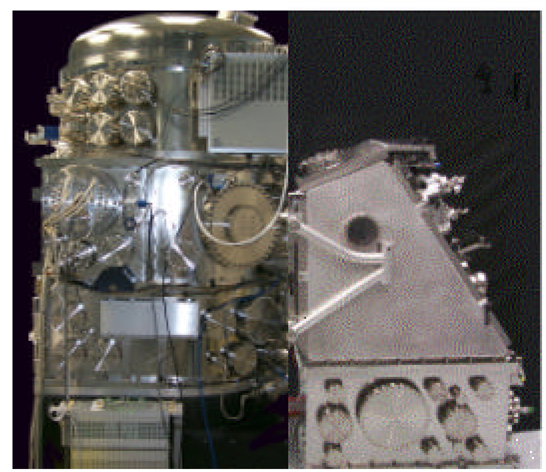


Alpha tool imaging provided in early 01



From CAD to Hardware





Main Chamber

- **Integration > 90% complete**
- **Initial environmental tests complete**
- **Produce full field scanned images 4/01**

Laser produced plasma source demonstrated

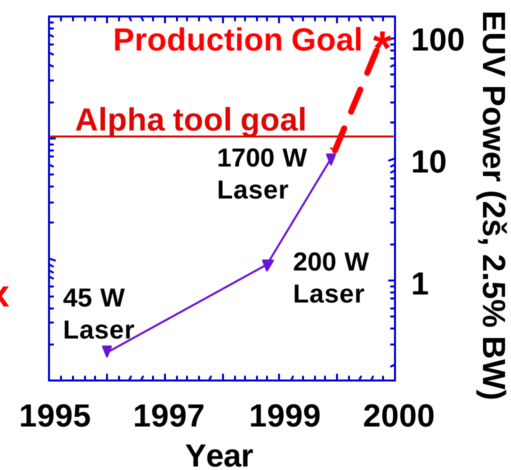
Xe Plasma
LPP at full power
1700 watts – 10 W
EUV at 13.4 nm

Source improvements
Identified to meet
80 wph production goal

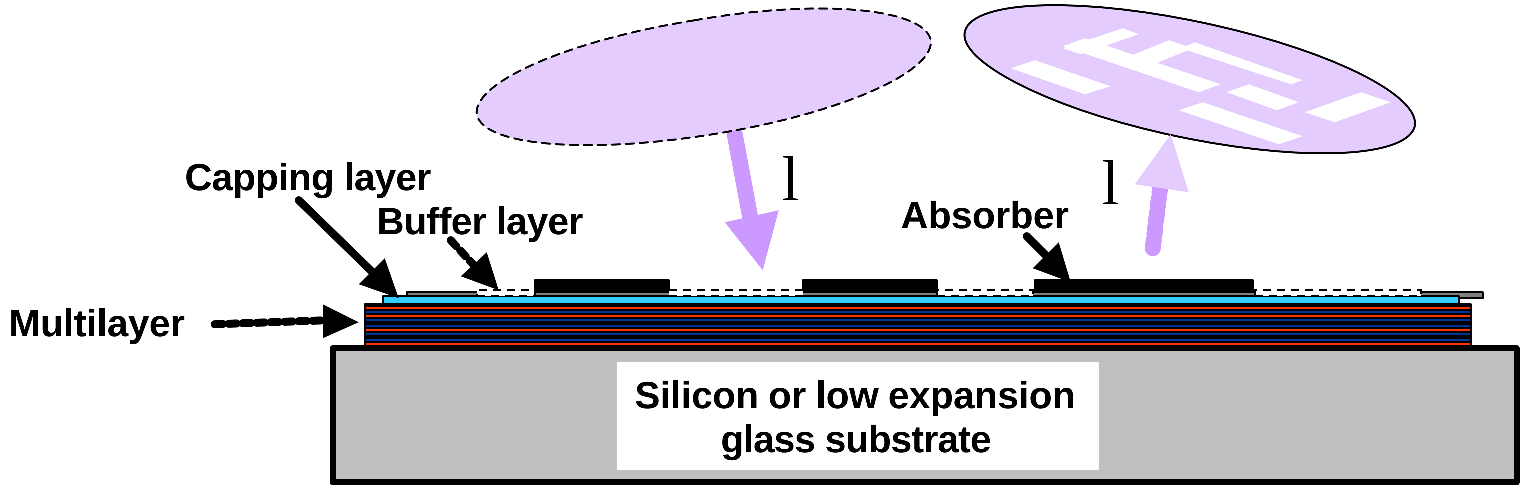
Improvements:

- **Conversion efficiency – 1.5x**
- **Collection improvement – 2x**
- **Laser power – 2-4x**
- **System improvements**
  - **Multilayer reflectivity - 1.3x**
  - **Filter improvement – 2.5x**

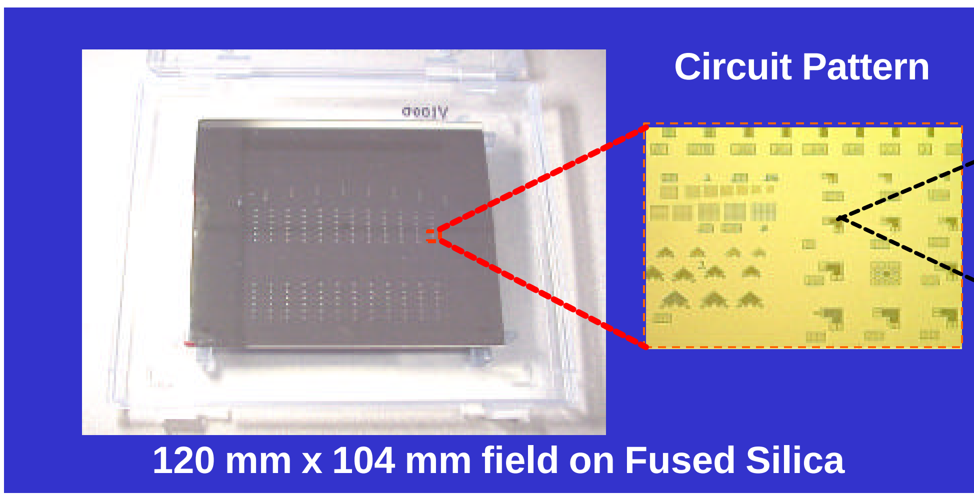
Total >20x

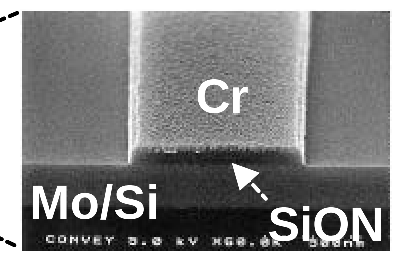


EUVL reflective masks fabricated



Mask Structure with incident and reflected EUV

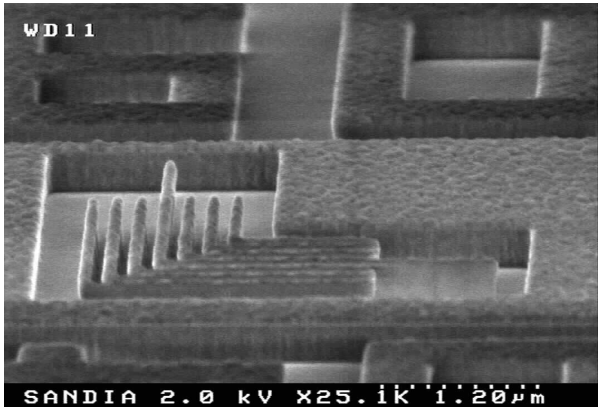




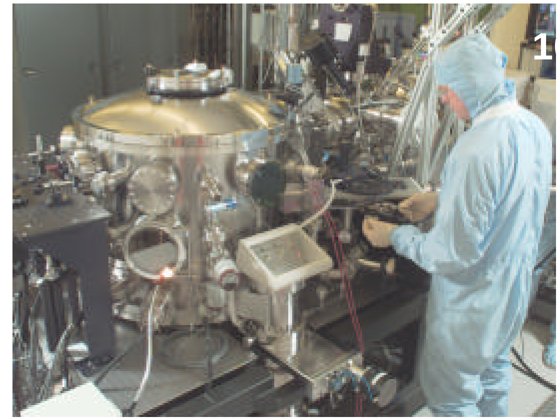
Mask Absorber Cross-section

Full Field Mask

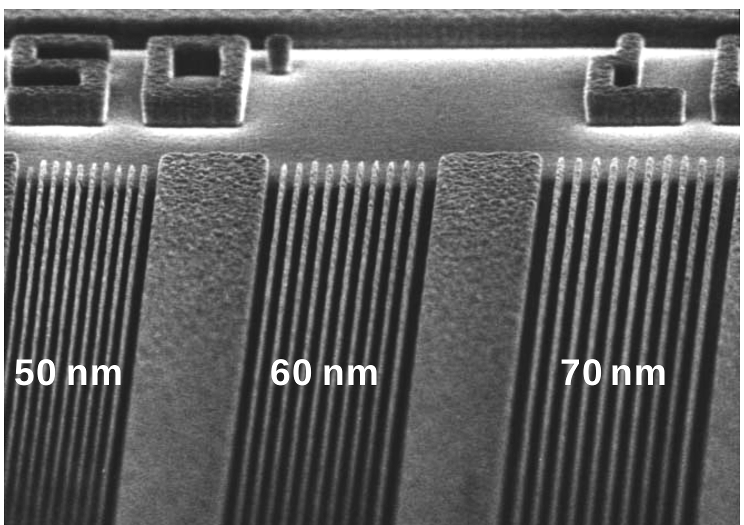
DUV resist extendibility quantified



90 nm Elbows in 350 nm polySi



10x Microstepper



- Use thin DUV resists
- Resist sensitivities demonstrated down to ~ 2.0 mJ/cm²
- Pattern transfer into hard masks has been demonstrated

Cost of ownership compares favorably

Estimated EUVL CoO compared to other lithographies

Parameter	157+PSM	EPL	Target EUVL
Node	**70 nm**	**70 nm**	**70 nm**
Throughput	**50 wph**	**20 wph**	**80 wph**
Tool price	**$16M***	**$15M**	**$18M**
Mask price	**$33K***	**$30K**	**$28K**
Cost/wafer	**$35**	**$52**	**$28**

* International SEMATECH values: May, 2000

Advantages of EUV Lithography

- Imaging follows optics resolution and DOF with NA and is expected to extend to <30 nm
- Uses robust 4x masks:
  - Easier to write and inspect than 1x
  - Less fragile than membrane masks
  - Low expansion glass substrates provide CD control
  - Uses existing mask patterning/inspection infrastructure
- Low NA optics provide good DOF and linearity for isolated and dense structures simultaneously without OPC
- DUV photoresists are extendible to EUV
- Wafer throughput targets ~ 80 Wafers/hour 300 mm
- Extends/leverages optical tool designs (scanning, overlay, optics fabrication)
- Projected affordable CoO with opportunity for extensions

Program Summary

- **Proof of Concept Alpha tool nearing completion – first images in Q101**

- **Technology feasibility demonstrated**
    - **Laser plasma source**
    - **Imaging using 10x microsteppers**
    - **Precision Masks**

- **Early tool development in progress at ASML and SVGL**

- **Cost of Ownership compares favorably with EPL and 157 nm**

- **No technology showstoppers identified!**